SOME GEOLOGICAL FEATURES OF THE BOULDER BATHOLITH, MONTANA.

THESIS

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INTRODUCTION.

The majority of the large metalliferous mines of Montana are closely associated with the Boulder batholith, and yet no report of any extent has been made on the intrusion as a whole. Several small districts have been thoroughly studied and reported, but the great distances which separate those areas make the reports in question of little value in giving any idea of the batholith in its entirety. From personal experience the writers have come to feel that the absence of any fairly complete description of the batholith, as a whole, is a serious hinderance to any study that might be made of local mining districts. And it is with the intention of removing this handicap to as great an extent as lies in our power that we take up this work.

Our interest in the district is due to several causes. First, is its tremendous richness for from the mines on this batholith has come more than two thirds of the wealth that places Montana ahead of all her sister states in value of metals produced. Then too, in this great mass of intrusive rocks are present the field examples of those great dynamical and structural problems which have seldom failed to excite a desire for a further knowledge.

Field Work.

Many of the facts herein presented were gathered during our three years' study at the Montana School of Mines in

Butte. During that time the Geology of the Butte district was frequently a point of study; surface features were investicated and mines visited. During the summer vacation the authors worked in several of the Butte Mines, and, also, at two mines near Helena. Likewise, during those three years the batholith was fairly well traveled over by us. Several prospecting and hunting trips, on foot and horseback, were taken as well as numerous journeys on all the railroads of the district.

The field work undertaken directly for this thesis was performed during the Christmas vacation of 1909. The batholithic area was first divided into three parts, the northern, central eastern, and the southern, then each of us endeavored to gain as complete a knowledge of these as our time would permit. The area is somewhat extensive, and inclement weather added to our difficulties. In spite of the latter, practically the entire vacation was spent in the study of our alloted areas. The work in detail follows.

The northern section was assigned to Mr. H.C. Sherman. The greater portion of the time was spent in the Helena district. Here the contact was followed from near Unionville, westward about eight miles to Blue Cloud, and later nine miles to near Alhambra. A third trip was taken ten miles toward Red Mountain, in the western part of the batholith. During all of these trips the adjacent mines were visited. Among these were, The Whitlach, Spring Hill, and Big Indian. Many specimens of the batholith material, vein matter, and the surrounding sedimentaries, both metamorphosed and unaltered were collected.

A three day trip was also made to Marysville near which the extreme northern end of the batholith was encountered. The great Drumlummon mine was unfortunately closed so only its surface workings could be visited. Numerous specimens of igneous rocks and intensely metamorphosed sedimentary beds were collected at Marysville.

The central part was studied by Mr. Bert Dyer. A three day trip was made to Elkhorn on the eastern contact. All the exposed areas were studied and numerous specimens collected. Visits were made to the most prominent mines, among them the Elkhorn, C. and D., and the Jaquemine. After leaving Elkhorn, the contact was followed from Boulder to Corbin, a distance of eleven miles. At the latter place the lately re-opened Alta Mine was visited.

The work in the southern part was performed by Mr. E. L. Ralston. Two weeks were spent in Butte in the study of both the surface and underground. As the snow was quite deep it was a hard matter to accomplish much on the surface, yet one third of the time was spent in examining and collecting specimens of the numerous outcrops and exposures. These specimens included "Butte granite," "Bluebird granite," quartz porphyry, rhyolite, and fragments of the outcrops of the old silver mines. The greater portion of the time was devoted to the underground study. Many of the largest mines in the camp were visited. Among them were the Speculator, Original, Stewart, Diamond, Belle, St. Lawrence, Anaconda, and High Ore. Besides these, attention was paid to numerous prospects and old abandoned mines. During all the visits, specimens of the country rock and vein matter were collected. Later, a trip was made to the western contact, and one to near the Highland mountains.

We returned to Salt Lake with about three hundred pounds of specimens. Representative igneous rock and more interesting sedimentaries were selected for special study. About six entire Saturdays were spent in making thin sections. A total of over forty slides resulted and the study of them has occupied our time for a month past.

Acknowledgments.

In our search for information on this batholith, we have followed up every possible source, so some of the enclosed facts come from widely separated points. No description of the intrusion, more than a few paragraphs in length, has been discovered, but by piecing together, we think we have here a report on the district more nearly complete than any that has yet appeared. For considerable of our information we are indebted to United States Geological Survey reports and private papers on local mining districts. From these we have attempted to glean such facts as might apply to the entire batholith, being careful in all cases to give the reasons leading to any conclusion reached, in order that our judgment may be checked.

During our field work authorities at the various camps and mines visited gave us much valuable information and extended many courtesies. This is particularly true of the

geological staff of the Amalgamated Copper Co. We are, also, much indebted to Dr. F. J. Pack of the University of Utah for many helpful suggestions and kindly interest.

HISTORY

The Boulder batholith is a large mass of granite situated in the southwestern part of Montana. Associated with the batholith are most of the great mines of the state. The first mining appears to have been performed in 1863 in the placers on Silver Bow creek, near the present city of Butte. One year later placer gold was discovered in Last Chance gulch on the present site of the city of Helena. Placer mining was also pursued at other places in and around the batholith. Although extremely rich, none of these deposits lasted more than a few years. Before their decline, however, the silver veins of Butte, the gold mines near Helena, and the silver-lead deposits near Corbin, as well as other leads were discovered. These inaugurated an era of mining activity that has continued to increase each year.

The first silver mining in Butte began in 1864. It lasted until 1898, the year that brought disaster to many silver mines of the west. The discovery of copper dates back to 1872 when a seam of copper glance a few inches wide was cut in a drift driven for silver in what is now the Anaconda mine. As depth increased the seam became larger, until at the three hundred foot level it was five feet wide. However, copper mining was not an important industry for a number of years, as the railroads had not yet reached Butte, and the cost of in 1879- the real date of the beginning of copper mining in the Butte district. Since then it has rapidly increased until in 1902 Montana took first place in the production of copper.

In the Helena district, lode mining began in 1865 with the discovery of the mines at Unionville, Park, and Montana City. These ores were treated during the first few years by crushing and amalgamating in arastras. These machines were superceded by stamp mills in the early seventies. Some silver mining was, also, done in the Helena district before 1875. The ore was hauled by ox teams to Corinne, Utah, thence overthe Union Pacific Rail Road, east. It was smelted in Swansea, Wales.

Another silver district of early prominence is located at Corbin, In this camp, the silver was associated with enormous bodies of galena and cerussite. The smelting of the lead ore soon became an important industry, so Corbin, Wicks, and Jefferson became, as a consequence, the scene of many of the early improvements in the metallurgy of lead.

The Elkhorn district was prospected early in the history of the state. In 1870, the A. M. Holter lode was located, which later beacme known as the Elkhorn Mine. At first the ores were treated by a five stamp mill which was wet crushing. This at first did very good work, but as depth was obtained the ores became more refractory, and as high as 50% of the silver values were lost. In 1883, a new ten stamp chloridizing mill was erected which increased the silver recovery to 90%.

The mill was used for some time, until it was changed to a concentrating plant. In this, the second class ore was treated, and the concentrates shipped, with the first class, to a smelter.

Another important occurance of ore near the batholith is in the Marysville district. In this camp was found the great Drumlummon which, unlike many other western mines, enriched the poor discoveror rather than an eastern promoter. This was the largest occurance of gold in the state, a 110 stamp mill being kept busy for many years.

In addition to the camp named above, several others have turned out much mineral wealth. Among these are Rimini, Bald Butte, and Gloster.

Geography.

The Boulder batholith is a large igneous intrusion which is exposed over an area of over 1500 square miles in southwestern Montana. Its most southerly point is in the Highland mountains, about sixteen miles south of Butte, and its northerly extremity lies about eight miles to the northwest of Helena. The easterly contact passes through Elkhorn, and the western passes a few miles from Butte. This gives an extreme length of about sixty-five miles, and a breadth of about thirty-five. The average length is about fifty miles, and the average width twenty-four miles. The greater portion of the exposure is in Lewis and Clark, Jefferson and Silver Bow Counties, with postions projecting into Deerlodge and Powell Counties. The center ofthe district lies at about 112° 15' west longitude, and 46° 20' north latitude.

The principal stream of the area is the Boulder River which has given its name to the batholith. The Boulder River is a small streamwhich rises in Jefferson County. It flows southeastward into the Beaverhead River, a tributary of the Jefferson, one of the three streams which unite at Three Forks to form the Missouri. The southwest part of the district is drained by Silver Bow creek which flows to the Pacific by way of the Deerlodge River and the Clark's Fork of the Columbia. The Continental Divide is thus seen to lie within the district.

A branch line of the Great Northern Rail Road from Haver and Great Falls traverses almost the entire length of the batholith, running, within it, almost continuously from Helena to Butte. The southeast corner is traversed by the Northern Pacific from about Rocker to Homestake. The Butte, Anaconda, and Pacific runs for a short distance on the granite near Butte, and the Chicago, Milwaukee, and Puget Sound for about fifteen miles from Butte southeastward.

Topography.

The Boulder batholith exhibit many fazes of a nearly mature topography although in local places this stage has not yet been reached. The region is well dissected, with numerous rounded elevations that possess rather steep slopes. Talus slopes are also a characteristic in many places.

Several rather broad valleys exist, at Elk Park, south of Butte, and near Clancey. The relief in many districts is great, a change of elevation of several thousand feet in a few miles being common. Cliffs are not numerous, and many of those that are found are caused by faulting.

The elevation of parts of the batholith vary greatly. At Helena the height above sea level varies from about 4800 to 6300 feet. At Marysville the elevation approximates 6000 feet. In the Boulder district a variation of from 5100 to over 6500 can be noticed. To the east at Elkhorn about the maximum height is reached on Elkhorn Peak 9,380 feet above sea level. This is approximately equaled by Red Mountain near Rimini, and by several peaks in the Highland Mountains. The elevation of the Continental Divide at Woodville, where the Great Northern R.R. crosses it is about 6400 feet with towering mountains on either side, reaching to 8000 feet. Butte is about 5800 feet above sea level, with the Big Butte some 900 feet higher.

Areal Geology.

The Boulder batholith lies in the semi-arid belt, the mean rain fall not exceeding 15 inches per year. This is about evenly distributed, one inch per month for all months save May and June. In these months the average is about two inches. Most of theprecipitation is in the form of snow, that which falls on the higher slopespersisting up to July. This has an important effect in that it prolongs the period during which placer mining can be pursued.

Many of the slopes are abundantly wooded, and almost all have a covering of grass. This is very noticeable along the contact where the green slopes of the granite area are contrasted by the bareness of much of the surrounding sedimentary region. A peculiar condition with regard to the vegetation has been noticed in many places. This is the inequality with which the different slopes are wooded. The north and east slopes are covered with more abundant vegetation than the western and SOUTHERN slope. This is explained by the fact that the summer sun has a more drying effect on the south and west than on the north and east. Also, in winter, the winds are prevailingly from the southwest and hence the snow is swept from the southwest slope to those on the northwest, being piled in great drifts, which serve to nourish vegetation until late summer.

As might be surmised from the above, the granite area is almost entirely covered with soil. This is true of all but the more precipitous slopes. As a whole the soil is not very thick. The greater abundance of soil on the granite area would indicate that rocks of that type weather somewhat easier than do the nearby metamorphosed sedimentaries.

The weatherED granite presents the appearance which is typical of such areas; great rounded boulders are numerous, as are, also, sharper aggregations which exhibit the unaltered places of joint planes. These give local variety to the open spaces and a scenic ruggedness of much interest. This is heightened by contrast; the southern and westernslopes appearing smooth, as all theiregularities are massed by vegetation, while the northern and western are studded with rounded boulders and sharp-edged masses.

It is claimed that the Great Northern ice sheets did not come as far south as the district in question. In several places glaciation has been noticed, however, probably caused by local ice accumulations. These indications are confined to the higher areas, being noticed on the slopes of Elkhorn, and, also, of Red Mountain. The glacial deposits are of no great extent, and consist chiefly of terminal moraines. One moraine is remembered near Red Mountain, which is of great interst. It consists of a great pile of angular granite blocks, on a flat, near the base of the mountain, and presents an almost artificial appearance. The moraine at Elkhorn is rather extensive, the town of Elkhorn being built upon it.

Stratagraphical Geology.

Along the more than two hundred miles of contact various kinds of sedimentary beds are exposed near the Boulder batholith. These embrace rocks of Algonkian, Cambrain, Carboniferous, Cretaceous, and Quarternary ages.

Algonkian; Belt Terrane .

The beds of this system are in contact with the batholith for more than fifty miles, and were the subject of somewhat extensive studies in several districts, so a detailed description is not out of place. The members of the Belt Terrane are part of a series laid down in a basin of subsidence which was formed during late precambran time. This basin appears to have extended from southwestern Montana northward into Canada and to have been about one hundred miles wide. Much of this area of Algonkain beds has been swept away by erosion, until at present, only a few scattered portions remain. Of these one lies near the Canadian boundary line, one hundred fifty miles north of Helena, and another is the Belt Terrane.

The Belt Terrane is at present exposed over an area about forty miles long and twenty-five miles wide, reaching from the Missouri River to the Continental Divide. The beds are found both in the Little Belt and Big Belt Mountains, whence comes the name for the series.

These beds were the object of considerable study by Mr. C. D. Walcott in his investigations into Precambrian Fossiliferous Terranes (bulletin of the U. S. G.S.). He has prepared the following table which shows the character of the beds, their thickness, and typical locality.

Formation	Thickness	Type Locality
Marsh Shale	300 feet	Marysville
Helena Limestone	2400 feet	Helena
Empire Shales	600 feet	Empire
Spokane Shales	1500 feet	Whites Canyon
Greyson Shales	3000 feet	Greyson creek
Newland Shales	2000 feet	Newland creek
Chamberlain Shales	1500 feet	S.E. of Neihart
Neihart Quartzite	700 feet	Neihart
	12000 feet	

In no place are all of these found, and frequently over large areas, only one is exposed.

Mr. Walcott has referred the beds to the late precambrian. He is led to this belief because they are unconformibly overlaid by middle Cambrian formations which were deposited upon a surface that indicates having been profoundly eroded. As the beds contained fossils seven thousand feet below their top stratum they probably were formed in late precambrian time. The fossils are said to consist of worm trails and the tests of crustacea.

Not all of the divisions mentioned in the table are anywhere in contact with the batholith. Those which do, or are in close proximity, may be selected for special description.

Helena Limestone.

This thick limestone member is typically displayed in the Helena district. It is exposed from Ten Mile creek, a few miles west of Helena, eastward to Townsend on the Missouri. The limestone is usually impure, and of a light gray or bluish-gray color. It is frequently oolitic, a description of such a specimen is included in the section under Petrography. In many places the Limestone is in direct contact with the granite, and for a distance of fifteen miles, near Helena, it is never far from the intrusion. Near the contact it has been altered in many cases to a very hard hornstone which is, with difficulty, distinguished from other beds of the series in like condition.

In a few cases, where pure, the limestone has been marbelized, and in one cast, at least, attempt was made to quarry it . Also, in places it has been mineralized so that when used as a flux, in smelting operations, it yielded as high as $2.00 in gold to the ton.

Marsh Shale.

The Marsh shale is, also, near the batholith in the Helena district. It is reddish in color andd grades from calcareous to quartzitic. Only about two hundred and fifty feet are exposed at Helena, this thickness increasing to one thousand feet near Marysville, twelve miles north.

The Empire shale does not come near the batholith except on the extreme north. Here they consist of soft calcareous laminae, grayish green or buff in color.

The Spokane formation is near the intrusion at various places along the entire eastern contact. It is found at the north near Marysville, near Helena, at Elkhorn and at Whitehall. The Spokane Shale is rather sillicious and of a deep red color. At Elkhorn, these become very hard and are known as the Turnley hornstone.

Cambrian Beds.

The Cambrian Beds are exposed near the contact at many places. They unconformibly overlie the Algonkian, although beds of this age slightly remote from the batholith rest on Arrachaen gneisses. All the Cambrian are of middle Cambrian age.

Flathead Quartzite.

This is the most common of the Cambrian beds near the contact, as it touches the granite at various places along the whole of its western edge. At Helena it consists of a thin remnant lying on the Helena limestone, directly at the contact. The quartzite is of a color varying from white, with a pinkish or yellowish tinge, to a dark brown. They are metamorphosed to a considerable degree, and, as will be observed later, in a description of the economic geology of the Helena region, they have had quite an effect in controlling the deposition of some ores. At Elkhorn the Flathead quartzite is, also, extremely hard, but not so dark in color. A thickness of one hundred and twenty-five feet has been observed.

Other Cambrian rocks around the batholith are of an intercalated nature, consisting of limestone, calcareous shales, and horn stones. No extensive study of them has been made except in one district. It is probable that beds of Cambrian age are abundant along the western contact.

Siluro-Devonian.

No extensive beds intermediate in age between the middle Cambrian and Carbonfireous are known. The Ordovician are entirely absent, and the Silurian are present only by inference from stratagraphical position. The Devonian is represented by two members along the central part of the eastern contact. One is a limestone formation about five hundred feet thick. The rock is very frequently altered to marbel, and is prevailingly light in color. The other known Devonian member is a shale-limestone series, about one hundred thirty feet thick. It has, in many places, been intruded by dikes, and is altered to a light colored jaspery material.

Carboniferous Beds

The Carboniferous rocks are probably the most extensive of any in the region. Strata adjacent to the batholith have corresponding members as far east as Fort Benton, and as far south as Livingston. Of these, the Madison limestone is close to the granite along almost the entire eastern edge. It is usually dark in color, and grayish from carbonaceous to argillaceous in character. The Quadrant formation, quartzites, and hornstone, has about the same extent as the Madison limestone, although only three hundred feet thick.

Mesozoic Rocks.

No Permian beds are known and the Mesozoic rocks do not possess sufficient lithologic unity to be subdivided. Both Jura-Trias and Cretaceous fossils are known but the dividing lines are not clear. Beds of the Mesozoic era are known, to a small extent, along the central eastern border. They consist of about seventeen hundred feet of alternating beds of quartzite, hornfels, sandstones, and some impure limestones of limited extent. These indicate a gradual shallowing of the sea which heralded emergence of the district in Cretaceous times. The very top of the Mesozoic is overlain by andesites which contain Paleocene fossils.

Cenezoic Rocks.

No marine rocks of the Cenezoic era are known in the district. The Tertiary is represented by river conglomerates and gravel at numerous places, by lake beds at some distance to the east in Smith River Valley, and to the west in the Deer Lodge Valley, and by valley fillings which are, in places, on top of the granite as at Butte. The Tertiary , also, includes andesite flows and the material of the batholith . The Quarternary is represented by glacial debris in places already mentioned, by soil on all the surface and by sand and clay in the valley bottoms.

The Batholith and Other Igneous Masses.

A statement of the position of the batholith with its dimensions has already been given.

The intrusion character of the batholith is unmistakable. Not only can its metamorphosing effect upon the contact strata be observed, but ,in several instances ,included portions of sedimentary beds have been found in the granite. One of the authors discovered near Marysville a xenolith of unmistakable character period. Several have already been observed along the eastern contact, two of them being rocks of limestone, one hundred to one hundred and fifty feet long. Dikes and sills from the granite mass are also seen to have penetrated the surrounding sedimentary beds. It can, also, be observed that the sedimentary beds near the intrusion have been altered in varying degrees. What are purer limestone beds at a distance, grade into marbel near the granite; impurer limestone exhibit garnet, wernerite, epidote, and other minerals commonly associated with metamorphosism, caused by a magmatic intrusion. Also, the quartzite and silicious shales are altered too dense hornstones, having several planes of fissility, which are missing from the unaltered portions.

The oldest marine bed, that the granite cuts, contains late Cretaceous fossils; but above the Cretaceous member is a flow of andesite which came to rest on an old eroded surface. This andesite contains Paleocene fossils. In many places the granite is seen to contain Xenolithic portions of the andesite and hence it is of more recent age than the Paleocene product.

In the Butte district, the granite is cut by an intrusion of rhyolite which was associated with a volcano. Ash from this volcano has been found in nearby lake deposits, and contains lake Miocene fossils. Therefore, The granite is earlier than the upper Miocene. Some of the volcanic tuff, also, rests on deeply eroded granite. This means that any cover which the granite may have had was removed, and the granite dissected before upper Miocene time. There is some reason to believe that the cover was not over one half mile thick. So no great length of time might have been used in its removal, and yet the facts mentioned are of some worth in making probable an assumption that the intrusion of the granite was pre-Miocene in age. These two deductions place the age of the batholith, with certainty, between the late Paleocene and the late Miocene, with a strong probability that either the Eocene or early Oligocene witnessed the intrusion. The diagram on the preceding page graphically showsthe age of the batholith.

This estimate as to the age of the granite applies to the entire intrusion. Mr. W. H. Weed,in his U. S.G.S. Folio 38, speaks of "The undoubted unity" of the batholith, so there must be nothing which would indicate difference of age of parts of it.

In next to the last paragraph mention was made of the probability that the batholith never had a very thick cover. It appears to be in order now to give the reasons for this belief, but perhaps it would be best to first give a few points on the form the intrusion.

Of the main type of igneous bodies it is obvious that only two forms need be considered. They are both the intrusive type, the laccolith and the batholith, as the theory that sedimentary rocks can be metamorphosed into a magma has long been discarded.

The typical method of laccolithic invasion is by splitting the sediment along their bedding planes, the upper portion then being domed by the hydraulic like effect of the intruding magma. If this were the method it would be reasonable to expect the contact to conform quite closely to the bedding planes of the sedimentary beds. This does not occur very often, however. Many cases have been observed where the granite cuts accross the beds at a high angle, sometimes having an almost vertical contact for hundreds of feet. In places, it is true, the granite dips under the sedimentaries at a low angle, but the occurrance is not as frequent as could be expected in a laccolith. The doming habit of laccoliths can also be used as a point to disprove the possibility of this method of intrusion for the mass in question. Remnants, of a former cover can still be found in the central part of the granite area, at a lesser elevation than some portions of the mass attain near its contact with the sedimentaries. This alone would disprove the possibility that the batholith ever, as a whole, had a dome shaped roof. A second point against such a shaped cover can be produced from elevation. The granite at Elkhorn reaches an altitude of nine thousand feet, while six miles west, at Boulder, it has an elevation of five thousand feet. This indicates an erosion of about a mile vertically (if the cover were dome) and yet no bottom can be seen. Also, if there were such doming of the cover the top of the magma would, in all probability, have been raised several thousand feet above its margin. This would require a considerable thickness of cover to prevent it from breaking through the stretched and broken strata along its sides. In such a case, surface flows of lava would be expected to form, but no such can be found. A further proof against a latholithic form is the tremendous extent of the igneous mass. Not only are two thousand square miles proved in the exposure, but the existance of apparently related intrusive rocks that Granite, the Scratch Gravels Hills near Helena, Gould, Granite Peak, and Gloster indicates that the probable extent of the intrusion reaches an area of possibly ten thousand square miles.

The laccolithic form thus being disproved, the only other possible one, the batholithic and an interesting question as to the manner of its intrusion arises. There are three possible ways in which the magma may have been caused to ascend to its present position.

1. There may have been no rocks there previously. This is improbable as no one could imagine the existence of a cave of such vast dimensions.

2. The magma may have, in some manner, moved the rocks out of the way. This could be done in several ways. (a) It may have pushed the rocks downward, but this would imply a laccolithic form which, as seen, does not exist. (b) The sedimentary beds may have been pushed to one side. This evidently could take place only in the zone of flowage. The sedimentary beds around the contact at the present time do not show any indication of such flowing. It could hardly be possible over such an area, as large as the one in question, as some of the matter displaced would have to move, with certainty, a distance of thirty-five miles, and possibly, twice that much. That such could be done and yet a roof of less than a mile in thickness remain unbroken seems impossible.

3. The third way in which the former rocks might have been FORMED is by marginal faulting which would allow the overlying block to be punched out. That this has not taken place cannot be positively proved. Several facts which tend to disprove the supposition exist, however. One of these has already been

mentioned; the alternation of a very steep and exceedingly flat contact planes. Perhaps the best argument against the hypothesis is that the following, a more probable one, has been proposed.

4. The former rocks may have been absorbed by the magma. That the magma has extended itself vertically, by absorbing the superincumbent strata, has, of all the hypotheses, the most points in its favor. By absorbing, is not meant actual assimilation by fusion in all cases, but in addition, very frequent inclusions of unfused portions. In assimilation by fusion, two methods are possible. One is, that the enclosing rock was gradually melted along the contact, and the other, that blocks were detached and sank into the magma. The first is said to have been disproved by comparison of chemical analyses of the wall rocks, and the granite. Great difference in the composition of the granite near the contact, and at more distant places has been noted in many cases but several explanations have been advanced. One is, that the magma may never have been entirely homogeneous, - a most rational theory. Another, is the very generally accepted theory of magmatic differentiation. From these, may be advanced the theory that marginal assimilation did not, perhaps, play a very extensive part in the upward advance of the batholith. There remains then the one possibility that the greater portion of the space occupied by the granite was opened by the wedging off of blocks of the strata, which formerly existed there. It has been shown that there are

strong indications that marginal assimilation was not extensive, hence the detached blocks must have sunk into the magma. Whether they were finally fused, is a question. If there is any bottom to the magma at any reasonable depth, they may have reached it, and possibly remain intact to the present day. If they sank to a considerable distance, in all probability, they were probably melted. It is generally considered that temperature increases with depth. That such blocks have been detached, is proved in several ways. The character of the contact in many observed cases, usually has a "step" form, for which the best assignable cause seems to be the one in question. Also, in several cases, blocks, which were apparently thus detached, are found included in the magma. Some of these were as high as two hundred feet long, and one third as thick. Not a great number have been found but their scarcity is explained when we remember that it would be only blocks falling after the magma had considerably stiffened which would fail to sink. This stiffening would also lessen the causes which produce the blocks.

The probable form of the mass and its most likely method of intrusion, having now been considered, the question of the thickness of the roof will be taken up. We have agreed that the batholith probably stoped its way up, so should not be surprised, if our observation indicate an exceedingly thin roof. Indeed, any thickness at all is a difficulty, for one of the most troublesome points in the whole theory of "stoping" by large intrusive bodies, is the assignment of a limit to their upward advance; that is, why has not this magma stoped its way to the surface and broken forth as a lava flow, instead of stopping somewhere in the interior of the earth. The granitoid texture of the rock, also, is considered as requiring a cover for their formation, although, the lowest possible thickness to produce such a texture, has never been determined. That the thickness, formerly considered necessary in order to produce a granitoid texture, is excessive, is very believable. In describing the sedimentaries, adjacent to the batholith, and in the discussion of the age of the intrusion, mention was made of an extrusive andesite which is found in many parts of the batholith. Also, inclusions of it have been detected in the granite at Elkhorn, near Whitehall, and at other places, while on the adjacent sedimentaries, it lies upon the topmost stratum. This would indicate that the granite had, in some manner, displaced, or absorbed the sedimentary bed, and had come to rest under the andesite. Hence the thickness of the andesite would be the thickness of the cover. On Elkhorn Peak, the andesite is, at present, one thousand feet thick. This has led to a supposition that two thousand feet represents the extreme probable thickness over any part of the intrusive area. This thin cover is contrary to the generally accepted theory, and needs further investigation.

Up to this point, whenever the material of the intrusion has been spoken of it was called granite. This was in accordance with the common habit of avoiding complications as long as possible. The rock of the Boulder batholith is not a true granite inthe technical sense. It contains two great a proportion of basic material to be granite, and yet possesses quartz in abundance. This would place it in the transition series between granites and diorites. At Butte, the rock takes the form known as quartz-monzomite, adamellite, holding this composition for quite a distance northward. In the northern half quartz-diorites appear. A discussion of the petography of these types will follow with others in later pages. Chemical analyses of specimens from various parts of the batholith have been made by the U.S. Geological Survey, and are given here.

	A	B	C	D	E	F	G	H
SiO_2	63.55	63.88	64.31	64.17	67.12	64.05	49.22	64.17
Al_2O_3	16.57	15.84	15.44	15.25	15.00	15.38	12.02	15.75
Fe_2O_3	2.36	2.11	2.43	2.16	1.62	2.20	2.77	2.16
FeO	1.98	2.59	2.58	2.98	2.23	2.74	8.80	2.98
MgO	1.53	2.13	2.21	2.60	1.74	2.08	9.29	2.60
CaO	4.69	3.97	4.22	4.24	3.43	4.30	10.56	4.24
Na_2O	3.78	2.81	2.71	2.62	2.76	2.74	1.90	2.62
K_2O	2.78	4.23	4.09	4.34	4.52	4.22	1.70	4.34
H_2O	1.42	0.88	0.98	0.81	0.67	1.10	1.90	0.81
TiO_2	0.42	0;65	0.71	0.67	0.48	0.60	0.95	0.67
CO_2	0.69	0.00	0.00	0.00	0.00	0.35	----	0.00
P_2O_5	0.21	0.21	0.22	0.16	0.15	0.21	0.43	0.16
SO_3	0.06	0.34	trace	0.97	trace	----	0.04	0.07
MnO_2	0.13	0.07	trace	0.04	0.06	0.11	trace	0.04

	A	B	C	D	E	F	G	H
BaO	0.15	0.09	0.07	0.07	0.07	0.08	0.03	0.07
SrO	0.04	0.02	trace	trace	0.03	0.04	0.03	trace
Li_2O	----	trace	trace	----	----	----	----	----
ZrO	0.00	----	----	----	----	----	----	----
Cl	----	trace	----	trace	----	----	0.08	0.00
	100.36	99.82	99.97	100.18	99.88	100.05	99.77	100.18

A equals quartz- diorite from near Marysville.

B equals quartz-monzonite from Walkerville.

C equals quartz-monzonite from Elkhorn.

D equals quartz-monzonite from head of Clancey creek.

E equals quartz-monzonite from near Boulder.

F equals quartz-monzonite from Butte.

G equals contact facies from Red Mountain.

H equals prevailing type near Helena.

These exhibits a striking chemical similiarity for rocks distributed over several thousand square miles. The greatest divergence is in the one, G, from the Highland Mountain. The difference may be accounted for, by the fact that it was selected in a bay which enters the sedimentary. The slight difference basisity is probably due to variation in the distances to the contact.

A petrographic study of these rocks is given later, but a discussion of the mineralogical variations as a whole seems more appropriate at this point, Specimens examined exhibit the following mineralogic composition.

	A	B	C	D	E	F
Orthoclase	33	22	15.6	25	19.2	33.9
Plagioclase	44	34	47.5	41.7	34.46	26.3
Quartz	15	25	22.2	19.4	23.7	37.7
Hornblend	5	9	5.5	6.8	15.3	----
Iron Ore	3	1	2	4.5	2.5	1.5
Biotite	---	7	7.2	----	4.2	0.7

A equals Quartz-Monzonite from Elkhorn

B equals Quartz-Monzonite one mile from contact at Elkhorn

C equals Quartz-Diorite from Marysville

D equals Quartz-Monzonite from Walkerville

E equals Butte Granite

F equals Butte Aplite

From the tabulation can be gathered the reasons for the names used. A monzonite is defined in Kemp's "Handbook of Rocks" as a transitional specie between the granite- syenite series and the diorite. That book says, "The monzonites contain orthoclase and plagioclase in approximately equal amounts, or, at least, both richly." This has been held to mean that neither felspar is greater in amount than twice the amount of the other, Therefore, three of the above readily come within the classification. The presence of free quartz necessitates the prefixing of that word to the name for the series. The rock "A" from the northern portion of the district is evidently not a monzonite, since there is three times as much lime-soda-felspar as there is alkali-felspar. This brings it close to the diorite in mineralogic composition. The universal presence of free quartz in considerable amount makes the modified term of quartz-diorite necessary.

It is thus seen that the Boulder batholith is composed of two closely related rock. Three fourths or more of the area yields the quartz-monzonite, while the extreme northern portion contains the quartz-diorite. The quartz-diorite is sparingly present in many places, but is chiefly developed in the small related exposure of the Marysville batholith, six miles northwest of the main intrusive mass. In places, the usual type of rock is replaced by a differentiation product, such as the near-gabbro of the Highland Mountains, and the syenites of Elkhorn and Marysville.

The quartz-monzonite has a uniform appearance over quite large areas, and yet when specimens from different districts are compared, variation, both in texture and composition, can be observed. As a whole, the rock are of the typical granitoid texture, but there is a large variation in the size and arrangement of the crystals. Generally, the dark minerals have no definite order of arrangement, but specimens exhibiting a faintly parallel arrangement are not uncommon. The amount of plagioclase is said to be noticably more abundant within a quarter of a mile of the contact. The Butte granite is considerably lighter than are the ordinary granites. The quartz is smoky, while the orthoclase is, in some cases, of the glassy variety Both of the felspars frequently exhibit pink cleavage faces. The chief difference between the quartz-monzonite and quartz-diorite is in the increase of plagioclase and decrease in orthoclase. This lessens its glassy appearance, and also decreases the pink tinge due to the orthoclase. The plagioclase crystals are rarely more than one sixth inch in diameter. Both the two chief types of rocks contain dark spots especially near the contact. These spots frequently attain a diameter of as much as four inches, but those under one inch aremore abundant. The spots are usually composed of the ferro-magnesian minerals, Very frequently these have decomposed so that on exposed surfaces many are changed to mere rust stain cavaties. Not more than a dozen of these spots were noticed in a walk of several miles near Helena, While at Marysville, as many were seen in less than one hundred yards.

Both of the rock types are, also, intersected by joints, which are of two general series. One of these is approximately at right angles to the other, but both are not always present. These joints have had a noticeable effect on the matter in which weathering has taken place. In the regions where both the vertical and horizontal joints exist the rocks break into brick like sections of varying dimensions. In other places, only one joint system is found.

Pre-batholithic rocks. The intrusion of the batholith was not the first igneous activity inthe district. Mention has already been made of an extensive occurrance of andesite which probably formed the only cover to the batholith. This andesite occurs as intrusive sheets, and as lavas, breccias, and tuffs. They have been found near Whitehall, at Elkhorn, at Marysville, near Helena, and inthe interior of the batholith. Other pre-batholithic rocks, are found in dikes and sheets in various districts. Of these gabbros are quite common and are, in some cases, older than the andesite. Dikes of diorite have also been seen.

Post-batholithic rocks. The post-batholithic rocks are of two general kinds. The first group comprises the rocks which are apparently an after effect of the batholithic intrusion. These comprise aplites, pegmatites, and acidic dikes in the granite. The aplites are found in a dozen widely scattered areas. That in the Butte district has been declared by Mr. W.H.Weed to be the largest known in the world. Aplites are supposed to be formed as follows: the basic material of thebatholithic magma was the first to crystalize, as it is the least soluble constituent. These crystals rose to the top, leaving the unsolidified magma in a more acid condition. Continued cooling caused the solidified portions to crack, the cracks as they were formed, being filled with the still molten underlying material, the aplite. The aplites have been found abundantly at Marysville and Elkhorn. At the latter place, a dike, four hundred feet wide, has intruded between the granite and the sedimentaries. The second of the post-batholithic rocks belong to the class called pegmatites. We have found them at Marysville, Unionville, and near Butte on what is known as the Timbered Butte.

Of the post-batholithic rocks, not clearly genetically associated with the batholith, several occurrances have been noticed. One of the most interesting is the rhyolite, directly west of the city of Butte. The rhyolite is of two main types, the intrusive, on the south, and the extrusive on the north end. This body cuts the granite and contains Miocene fossils. The rhyolite forms the Big Butte, a solitary peak west of the city. This peak is the most noticable natural object in a radius of many miles, and used to be a land mark to guide the prospectors to the "Summit Valley" placer diggings. It was not long before the former name was forgotten, and the camp was called Butte City.

Other post-batholithic igneous rocks are found. In the northern portion extrusive andesites are found, lying upon eroded granite. In some extreme cases they occur as volcanic glass, but usually consist of breccias. One such mixed mass is a half mile long and one hundred feet thick. Dikes of basic rocks are also found, which cut the granite in various places. One near Helena is filled with diabasic material.

Hot Springs.

One of the interesting features of the batholith is the numerous hot springs. These are caused by still uncooled magma, in depth. They are found at the Broadwater near Helena, the Alhambra, near Clancey, the Boulder, near the town of that name, and the Gregson, west of Butte. The Boulder hot spring is very interesting from a geological standpoint, as it is depositing gold in the sinter, at the spring opening.

Economic Geology.

As could be expected from the extensive territory and the number and variety of mines, many different kinds of ore bodies are found. These are grouped into several large mining districts, so a description of such districts, as units, appears to be the most reasonable method.

Helena District.

Although Helena is three miles north of the main contact, it has a few small gold mines almost inside its borders, and in addition, is situated upon the old Last Chance Gulch placer. Southward to the batholith, and east and west, along the contact for a total distance of fifteen miles prospects have been opened, and not a few developed into paying mines. Indeed, it is a difficult matter to find a place on the contact, from which cannot be seen, one or more mines that have produced heavily.

The Last Chance placers were discovered in June, 1864, on what is now the site of the city of Helen. Placer mining was pursued vigorously for fifteen years, and is even yet carried on successfully in the upper tributaries of the main gulch. The total amount of placer gold produced in the district to date is conservatively estimated at twenty million dollars, making Last Chance Gulch second only to Alder Gulch, among Montana's great placers. With their California experience, many of the placer miners began a search for the "Mother lode", from which this great amount of wealth had come, and the hunt is still in progress. When the Whitlach and Park veins were discovered, four miles up the main gulch, the source of the gold was thought to be found. Others did not consider that these leads, which though rich, are small, could have been the place of origin. Later the extensive low grade ore bodies of the Spring Hill were discovered in the same gulch, and the attention was directed to it, as the sought for"mother lode." This left out of consideration the fact that extensive placer gold had been taken from the gulch above the Spring Hill, a point that applies to the Park and Whitlach veins as well. No other occurrance of gold in place sufficiently large, and in the right location, has been found, so the source of the gold is still an open question. The difficulty lies in the attempt to find one large deposit which could have distributed such an enormous amount of gold over ten miles of gulch bottom. Undoubtedly, all three of the ore bodies mentioned contributed a portion which was added to from other sources. Quite numerous small veins are found in the granite, and although they are generally less than a foot wide and carry no more than $1.00 in gold to the ton, they must have been a factor in the enrichment of the granite.

Before describing any of the individual lodes mines, mention might be made of an exceedingly interesting condition, to which attention was called during the field work. The first point is the apparent continuity of the different bodies into two great veins about ten miles long. A second point, is the rough parallelism of the two systems. They are never more than a mile apart. A third is the unexplainable fact, that they dip in just exactly opposite directions, the northern vein dipping at 45° or less to the north, and the southern vein at the same angle at the south.

The largest producer of the entire distict is the Whitlach, with a record of about four millions of dollars. It was first opened about 1865, and is still producing. The lead outcrops on the surface for several hundred feet, the upper ore being of great value. Several incline shafts were sunk in the granite for a distance of nine hundred feet, and a great tonnage of ore removed. This was crushed in a thirty stamp mill. The mine was closed about 1880, and remained idle until about 1902. A new company then, by a four hundred shaft, mined what ore had been left below the old workings. This kept a twenty stamp mill going for about three years. Work was again practically stopped in 1907 with no great prospects of speedy renewal.

One of the writers worked in this mine for about six weeks and paid a visit during the Christmas vacation, so a few points about its geology were obtained. The ore occurs in a fissure vein. Indications "comb" structure and the presence of pegmatites point to an open fissure, but as the ore is highly irregular in width, these openings were probably not extensive or continuous. The ore on the surface is oxidized, but at about the three hundred fifty foot level, sulphides are encluntered. The gold is more than three fourths free. Very little silver or lead is present. Copper carbonate is found. Secondary enrichment has played an important part. This is proved by the fact that the ore is richest along fault plains, through which the water could percolate. The ore continued to a depth of four hundred fifty feet vertically, but on the five hundred foot level, the vein has become almost entirely barren. This would indicate that the five hundred foot level has penetrated the area between that below, in which the gold was dissolved, and that above, in which the gold was precipitated. That is, at, and below, the five hundred foot level, conditions were not such as to cause precipitation of gold from the ascending solutions. It might be said that the five hundred foot level is too near the surface to possess such conditions, but it must be remembered that several hundred more feet of granite, as well as considerable sedimentary cover, existed there when the vein was formed.

Adjoining the Whitlach, are several small producers, among them the Mack. In that mine the more is found directly beneath the Flathead quartzite. The same phenomon occurs in the Nonesuch mine, in Arastra Gulch. The supposition is that the ore bearing solutions coming from below were compelled to deposit their lode beneath the quartzite which, at the contact has been altered into a hard impervious hornstone.

On the west side of Grizzely Gulch is the Park mine, the second largest on the south dipping deposits. It resembles the Whitlach in all essential respects. No other mine on that system of deposits has produced more than a few thousand dollars.

The largest mine on the south dipping veins is the Big Indian. The Big Indian contained an immense tonnage of low grade ore. It supplied a ten stamp mill for five years, one of fifteen stamps,for the next five years, and one possessing sixty stamps, for three years more. It was closed about 1906, but has lately been re-opened. Most of the ore was taken from an open cut, this being so economical a method that the total cost of mining and milling was not over one dollar per ton. The deposits consisted of a number of small veins inthe granite. The granite also was frequently richly mineralized. A striking peculiarity was noted in this deposit by Mr. W. H. Weed. That is the association of gold and tourmaline. He has used the Big Indian mine as the example of a tourmaline-gold producer mentioned in his famous classification of ore deposits.

The second largest mine on the south dipping vein is perhaps the Shober. Others of prominence are, the Uncle Sam, San Juan, Black Swan, Geezer, and Yellow Boy. All of these have produced many thousand dollars apiece.

Besides the above, many other smaller producers could be mentioned that belong to one or other of the two veins. All in all they have produced more than ten million dollars. Perhaps the best impression will be given when we state that on these various mines there have been erected, since 1865, although many have since been torn down, a total of two hundred and forty stamps,besides several arastras and mills of other types.

Elkhorn District.

While neither the oldest nor richest mining district associated with the Boulder batholith, Elkhorn has been more completely studied than any of the other camps,not even excepting

Butte. Many times more work along geological lines has undoubtedly been performed in the big copper camp, but the tremendous problem there presented makes the results less satisfactory. In particular, can be praised the Elkhorn report of Messrs. Weed and Barrell, which is found in the twenty second annual report of the Geological Survey.

Like so many of its neighboring mining camps, the Elkhorn district is situated on the margin of the batholith. To the west one sees the granite mountains that continue for thirty miles to the Deerlodge Valley. To the east are sedimentary beds of quartzite and limestone, deeply dissected, and generally unforested. And all about are the evidences of former volcanic activity, with a few instances, on the higher slopes, in which the one time highly heated material has been built into moraines by glaciers.

The sedimentary beds mentioned all dip eastward away from the granite at an angle of about 45°. They comprise the eastern limb of a great anticline, the western portion of which formerly occupied part of the present area of the batholith. The rocks are extremely altered so no fossils have been found in the immediate vicinity. The beds are of many ages. At the base occurs a stratum of limestone, four hundred feet thick, which is believed to be a member of the Spokane shale, a central member of the belt series (Algonkian). Above this comes the middle Cambrain quartzite and limestone, totaling twenty-one hundred feet. Following, is a hundred foot bed of hard shale whose age is indefinite, being either Silurian or Devonian. The Great Madison limestone, nineteen hundred feet, is next, and is overlaid by the quadrant sandstone and quartzite. Both the Madison and Quadrant are of Carboniferous age. Only one other marine bed is known, a Cretaceous member consisting mostly of sandstone and other near shore deposits. The post-Cretaceous non-igneous deposits consist of glacial moraines, soil and aluvium.

Pre-batholithic igneous rocks are found in considerable abundance and varitey. These rocks are usually found in dikes and sheets, and as might be expected, are basic in character-gabbros and diorites. The most widespread of the pre-batholithic igneous rocks is an extrusive andesite which is found to be one thousand feet thick on Elkhorn Peak. Post-batholithic rocks comprise aplite, syenites, and quartz porphyry. One aplite mass several hundred feet thick has intruded between the quarts-monzonite and the adjoining sedimentaries.

The Elkhorn mine is the largest producer in the district. The record is over six millions of dollars, mostly in silver. The mine was located in 1875, and was worked continously to 1899. After a few years of idleness operations were again resumed, and continue to the present. The mine is developed by a twenty-three hundred foot shaft, inclined from about 35° to 55° from the vertical.

The ore is not found in the granite, but occurs as a replacement deposit, in middle Cambrian limestone and quartzite.

The ore is of two kinds. One is an argentiferous galena, with quartz, pyrite, and some zinc blend. This is smelted at East Helena. The other is a quartzose ore carrying argentiferous led carbonates and oxide. This was treated by amalgamation in pans. As depth was obtained, galena and tetrahedrite increased in amount, causing trouble in the mills. A chloridizing roast is necessary for this class. The ore bodies are of great size, in many cases. In the upper levels only one large body is found, but at three hundred and fifty foot depth this splits into two main diverging shoots.

As said, above, the ore is a replacement deposit in quartzite and limestone. The main ore bodies are found along the contact between the two. The quartzite member is above and has been altered to a dense hornstone. Below is the limestone, dolomitic in character. At times the ore is found in the hanging wall, and at others, in the foot wall. It is generally the case that the former is milling, while the latter is a product for the smelter. The following interesting point has also been observed. The ore occurs on the underside of anticlinal folds in the country rock. Mr. Weed has called this a"saddle" deposit similar to the Bentigo deposits of Austrailia, and has mentioned it, as an example of such, in his classification of ore bodies.

This method of occurrance, when considered with the character of the country rock, is a valuable aid in determining the origin of the ore deposits. The limestone is not hard or compact, but offers a ready passageway for solutions. The over-

lying quartzite has been altered to a dense impervious hornstone. Now the fact that the ore occurred beneath an impermeable layer clearly indicates that the solution came from below,while the deposition on the under side of small folds in the upper compact stratum makes the accuracy of the conclusion undisputable.
If farther confirmation of this is necessary, it can be gathered from the following. On the twenty-three hundred foot level, the ore is found to play out, and in its place, is a barren type of quartz. At first glance, this would seem to absolutely disprove the contentionthat the ore was brought in by ascending solutions, but when farther examined the exact reverse is found to be true. It is generally conceded that dissolving of the common ore minerals requires solution having special qualities, due to pressure, temperature, and to the contained "mineralizers". These are probably found only in depth. As the surface is approached, these qualities are lost, and the zone of solution is left behind. The continued reduction of the solvent power finally causes precipitation to commence, and proceed at a more rapid rate as the surface is neared. But it is reasonable to believe that between the zone of solution and that of precipitation, there is a considerable area in which the solution neither has power to increase its load,nor is compelled to deposit any of the dissolved metallic minerals. Such a place would result in a barren zone beneath the ore body similar to that on the twenty-three hundred foot level of the Elkhorn Mine.

The source of the metallic content of the ore is not definitely.known. The gabbro in the neighborhood is a possible source, as they are rich in augite, mica, and iron ore. It is possible that the gabbro was leached in depth, by solutions whose activity is due to heat and mineralizers from the nearby batholith. It is not certain that the ore is younger than the batholith. However, that such is the case, seems probable from the following. The deposition of the ore was controlled by the imperviousness of a hornstone stratum. The hornstone is an altered shale, the metamorphosism of which is most reasonably ascribed to hydrothermal activity , excited by the nearby intrusion.

The rising solution which brought in the ore were silicious in character as is shown by quartz veins in the dolomite. The proximity of the batholith indicates that they were probably hot and the occurrance of axinite and tourmaline give a clue to the associated mineralizers.

The mineral of economic importance are native silver, horn silver, silver sulphide, galena, cerussite, and lead oxide. With these are associated pyrite, tetrahedrite, and other copper minerals, bismuth sulphide, zinc silicate, zinc sulphide, and a few iron and manganese minerals. Native copper is also found. The silver content is the object of the mining, although the lead is saleable and makes possible a lower smelting rate. The native silver is said to have been phenomenally abundant in the upper level.

The gangue minerals are quartz, calcite, dolomite, and such minerals as garnet and serpentine.

The Elkhorn is the only large mine in the district, although a half dozen others have produced a few thousand dollars. Several of these are sources of supply of iron ore used as a flux by the East Helena Smelter. The iron is regarded as an oxidized pyrite and usually carries over a dollar per ton in gold.

In this district is also a mine named the Dolcoath which, although small, is one of the most peculiar mines in Montana. It is generally said to be the only mine in Montana that contains true contact ore deposits. W. B. Scott in his Introduction to Geology quotes Mr. J. E. Spurr as follows; "The ore bearing stratum of the mine was originally a bed of impure limestone which has been metamorphosed to garnet and pyroxene with spots of calcite. Associated with the gangue minerals are sulphide and telluride of bismuth, containing gold." The ore is found about a half mile from the batholith. The association of gold and bismuth minerals is uncommon. It is also a matter of interest that this mine contained the only free gold in the district.

Although the Elkhorn and the iron producing mines are still being operated, it is probable that no extensive mining will ever again be done in the immediate vicinity.

Marysville District.

The Marysville District is not on the Boulder batholith. It lies on the margin of a quartz-diorite boss, six miles north-east of the northern most exposure of the Boulder batholith.

And yet it undoubtedly belongs to this discussion, for there is not the slightest doubt but that the true igneous exposure become one mass in depth. This is proved by the similiarity between the material of the two batholiths, and by the presence of dikes and other igneous masses in the six miles that separate the two.

The Marysville batholith is about three miles in greatest length by one and three fourths miles in greatest width, with an area of about two and one half square miles. It is immediately surrounded by metamorphosed sedimentary beds, the Marsh shale and the Helena limestone. Farther away are other members of the Belt series, but they are not so greatly altered. The metamorphosism of the shales and limestone altered them to hard silicious hornstones. Very frequently they are banded by layers not over an inch in thickness. These give a striking appearance to many of the cliffs of the district.

A petrographic description of the rock of the batholith, and of some of the other igneous rocks is given in the later pages. Th e rock is typically a quartz diorite. There are two types of this rock - one rather coarse grained and of uniform appearance, the other finer grain with less dark mineral.

In and about the intrusion are other igneous rocks, some earlier and some later than the batholith. The former include dikes of diorite and gabbro, and some felspar- porphyry. A specimen from one of the latter is described later. As usual, the post-batholithic rocks include apelites and pegmatites. In addition, dikes of basic rocks are found cutting the batholith.

To the north there has been an extrusion of andesite upon the granite.

The Marysville district is reached from Helena by a branch line of the Northern Pacific R.R., eighteen miles long. The town was built up by the mining industry, and at one time, had more than two thousand inhabitants. There are several large mines there, Drumlummon, Bald Butte, Belmont, Penebscot, etc., which have produced a total of over twenty million dollars, thirteen millions of which came from the Drumlummon alone.

The fissures in the district are quite numerous and yet can be grouped into two classes. One class comprises fissures approximately parallel to the contact, and the other fissures at a high angle to the contact. This is in accordance with the theory that the margin of the batholith, cooling first shrunk away from the center, this causing periphal faulting, while the lessened circumference would tend to cause radial faulting. In the center of the intrusion, these fissures are no more than joint planes, and are never mineralized. Toward the margin and in the metamorphosed zone they become extremely large, and are frequently ore bearing.

In the Drumlummon mine the veins are found to be branched and intersected. The main vein is typical of the others, however. The vein varies from ten to forty feet in width, and yet there is apparently no great displacement. The fissure was first filled by a mass of broken debris from the walls. These pieces were cemented and at times replaced by barren silicious waters. This is proven by the finding of pieces of shale in the quartz filling. A second movement allowed the mineral varying solutions to enter. They have deposited their mineral as a rich coating around the barren quartz and shale. The mineral varying solutions did not act along the entire length of the fissure, but only in channels, so the mine is characterized by barren spots and rich shoots. Ore was found to a depth of one thousand feet but prospecting was carried five hundred feet deeper. This vein with the related ones produced an enormous tonnage of ore. The mine was purchased by a London concern, and was operated for many years. Several mills were built, and at one time, a total of one hundred ten stamps were crushing ore from this mine.

Among the branches of the Drumlummon vein are two called the Old and New Castleton. The former splits away from the main vein, and runs parallel with it for over three hundred feet, presenting the appearance of a double vein. It then diverges at an angle of thirty degrees and later at one of sixty degrees. The space between the two veins is frequently in a very broken condition. These veins do not always cut the dikes in their path, but run parallel with them. The fissures are older than the granite, and are, also, more ancient than many of the others. The gold is associated with siderite and an iron-magnesium carbonate.

The Belmont veins belong to the class running at a high angle to the contact. They are split into many members. The ore was all above the four hundred foot level.

The Bald Butte mine, southwest of the batholith in the metamorphic zone is still running, and has paid dividends regularly for many years. The veins are filled fissures in hornstone. Nearby is a dike of Rhyolite.

There are several other large mines in this district, all on fissure veins. Marysville has been the largest gold producer in Montana, and is far from worked out yet. Several mines are still running. In February, the litigation between the Drumlummon Company and one of its neighbors was settled, so there is prospects of an early resumption of work on the largest and richest lode in the camp.

Wicks-Corbin District.

The Wicks-Corbin District is primarily a lead and silver producer. The mines in that region were the ones that placed Montana high up as a lead and silver producer during the late seventies, and the eighties. As a result, the town of Wicks can lay claim to being the birthplace of many of the improvements in concentration and lead smelting which have revolutionized those industries. The production was enormous, as can be judged by this; The silver bullion was shipped to Helena to be transported East, and it is said that the first train (N.P.R.R.) that left that town (1883) carried twelve million ounces of silver bullion.

Among the mines of the district, the Alta at Corbin, stands preeminent with a record of thirty million dollars. The ore is in a vein in andesite, and was remarkable for its persistancy and regularity. It was worked for a distance of five thousand feet horizontally, and yet no cross fault was found. The vein was frequently one hundred feet wide, and consisted of argentiferous galena in quartz.

In the same district, is the Ruby mine which appears to be a chimney of boulders of rhyolite coated with gold bearing silver sulphide. The nearby Bertha mine possessed large bodies of lead carbonate near the surface. This district has been in a decline for a number of years. Last year, the Alta and several other mines were again reopened.

Rimini District.

The Rimini District is on a branch of the Northern Pacific R.R. from Helena, and is twelve miles southwest of that city. The camp has several big mines, and has produced abundantly. One of the mines is the Lee Mountain, a steady producer. Another is the Porphyry Dike. In this, the fissures cut accross both a granite, and a rhyolite. In the former, they are small and tight, but open out in the latter into wide fissures, ill-defined and more like bands of shattered rock. The entire mass is mineralized, presenting a very large body of low grade ore.

Butte District.

The Butte Mining District covers an area of about four by six miles, in Silver Bow County. The region is very barren, and is distinguished by gently rounded topographical forms which are largely due to the rapid disintegration of the surface rocks. In the center of the district, stands a sharp cone generally known as Big Butte, which was formed by ejected rocks sometime after the mineral veins originated. Water is very scarce, the only streams being Silver Bow creek and its Butte tributaries.

The city of Butte lies to the east of the Big Butte, the greater part of it lying east of Missoula Gulch, a north-south depression a few hundred feet east of the Butte. To the west is a minor depression, known as Dublin Gulch, which is nearly parallel to Missoula Gulch. Most of the copper mines including the Anaconda, the richest in the camp, are situated near the head of Dublin Gulch.

In the early sixties, the gravel of Missoula Gulch was placer mined for gold, but owing to the scarcity of water, it was not very profitable. It was largely due to this and to the prominence of outcrops of mineral veins that led to the beginning of deep mining. The placer soon was soon exhausted, and the district nearly abandoned, until 1875, when rich silver ore was discovered in the Trovona lode. Butte rapidly changed from a gold camp to a silver camp. The Washoe process proved a success, and the Moulten, Alice, Lexington, and Blue Bird mills were constructed to treat the ore. That these silver mines were very rich and good producers is proven by the fact that the Lexington sold for one million dollars. However, silver mining did not last long, for the price of silver decreased, and the mines have not been worked since except by lessees.

Some copper mines to the westward of the Parrot lode were worked during the early days, but these were abandoned as the ore could not be economically smelted. It was not until 1879-80 that copper mining was permanently established and the Colorado smelter was built. A few years later, the Parrot and Calusa smelters were built to treat the ores of the respective mines.

In 1881, a railroad was built into Butte. Since that time the copper industry has gradually increased , bringing Montana into first rank among the copper producing states. The city grew rapidly from a small cluster of miner's cabins ,to the largest city in the state, having a population of about sixty-five thousand. The first smelters built in the district have been dismanteled long ago, the their place has been taken by four others, the Washoe at Anaconda, the Boston and Montana, at Great Falls, and the Butte Reduction Works, and Pittsmont smelter at Butte. At the present time, the mines are nearly all owned by two companies, the Amalgamated Copper Company owning the greater percentage, while W. A. Clark still has a few. The principal mines of the district, are the Silver Bow, Berkely, Grey Rock, Moonlight, Tramway, Mountain View, Leonard, Colusa, Anaconda, St. Lawrence, Diamond, Never Sweat, High Ore, Speculator, and Mountain Con.

The Butte district is one of the great copper producers of the world. With the exception of 1906-07-08, Montana led in the production of copper since 1902. Up to 1897, it is estimated that the Butte district produced over five hundred thousand ounces of gold, one hundred million ounces of silver, and one billion, six hundred million pounds of copper. This district, alone, produces about eighteen per cent of the gold, and eighty per cent of the silver of the state. All the gold and silver obtained now is a by product from the copper ores. The Washoe smelter at Anaconda makes one sixth of the world's copper. The production of copper for the Butte district in the year 1909, is estimated by the U. S. G. S. at three hundred ten million, five hundred thirty-two thousand pounds, thereby leaving Arizona, the next in rank, by approximately nineteen million pounds. The great fissures of the Butte district are supposed to have been formed by the cooling of the granite mass. These fissures were filled by the more acidic granite, the aplite, or Bluebird granite. Another set of fractures was undoubtedly formed by some dynamical movement, which was closely associated with an intrusion of quartz porphyry. That there was some dynamic movement, is proven by the intrusive bodies of quartz porphyry, and by the seams of fine fault material of earlier age than the ore deposits.

The main fracture which admitted the mineral bearing solutions were formed later than the intrusion of quartz porphyry since the vein fissures cut off of these rocks. After the veins were formed, fracturing again took place, and, also, the intrusion of the rhyolite since all the veins are cut off sharply by it.

Vein fissures have been controlled in their direction and persistance by the relative homogenity of the rock masses. The veins of this district are very uniform in direction. The great veins of the district strike east and west, those being the first to form. They were followed by the northwest fault veins. The last veins to form were the northeast fault veins, which are not nearly so highly mineralized as the other two series. The copper bearing area seems to be the center of the mineralization.

There are two well defined systems of faults, strike faults and dip faults. These strike faults vary from a few inches up to many feet in width, and in the upper part of the mines they contain so much moisture that the vein filling strongly resembles mud. They usually have the same dip as the veins. In a few places, dislocation has been noticed, but the displacement of the veins is hardly noticeable. The dip faults while not so great in number, are more noticeable because they usually cause a slight displacement of the vein, and are generally at right angles to the vein. It is generally believed that both of these systems of fissures have been channels for the water descending from the surface, which has produced the secondary enrichment.

The valuable ores of the Butte district are found entirely in the older rocks-granite-aplite, and quartz porphyry. Much prospecting has been done in the rhyolite, but all efforts to find ore deposits in it have failed. With a few exceptions, the copper ores are found entirely in the granite, while the silver ores are found both in the granite and the aplite. The deposits are divisible into two classes. The district west and south of the Butte does not contain any copper bearing minerals, and is essentially, a silver district. In regards to depth, there is some doubt as to whether the silver veins decrease or not, but it is generally thought that they do. This is not true of the copper deposits, because the ore found in the deepest levels is as rich as any that was found above. All copper ores of the district carry both gold and silver in small amounts. All silver veins are characterized by a high percentage of manganese, which is rarely found with the copper minerals. Much zinc is associated with the copper and the silver ores. There is a small amount of lead, but it is not of any economic value.

The ore deposits have been formed by ascending alkaline aqueous solutions which have gathered into the faults and fissures. The source from which these metallic minerals have been derived is not definitely known. It is thought that they come from some rich part of the granitic mass in depth. Since the granite at the surface contains a small amount of these metals, this theory has some probability. The ascending solutions they have been at a very high temperature and pressure. When the fissures were large enough a true fissure vein deposit was formed, but in most cases, the solutions penetrated and attacted the adjoining wall rock, forming the replacement deposits. Besides the above types small cross fractures and joint cracks have been filled. In general, this may be stated that the copper veins are usually replacement veins while the silver veins are usually of the fissure type.

Secondary enrichment has played a very important part in this district. It is not due to the oxidizing action of the surface water alone, but below the zone of oxididation it has formed rich copper minerals ,bornite, chalcocite, and cobelite, by the breaking up of the original chalcopyrite. The formation of these minerals may have been influenced by the intrusion of the rhyolite. The enrichment of the copper deposits is so closely associated with the secondary fracturing, that it may be considered a genetic result of it. The silver deposits have been enriched but slightly.

The ore minerals in the Butte district are pyrite, chalcopyrite, bornite, chalcocite, enargite, sphalerite, galena, rhodonite, and rhodocrosite. Others less common are, tetrahedrite, covelite, tennantite, native silver, argentite, pyargyrite, calcite, gypsum, bayrite, and fluorite. The oxidation products are, hematite, lymonite, vivianite, cuprite, melaconite, native copper, chrysocolla, malachite, azurite, chalcanthite, cerussite, pyrolusite, manganite, psilomelane, and wad.

Petrography.

Gabbro from Black Butte, Elkhorn.

This rock is thought to have been the mineralizing agent for the mines at Elkhorn. The ground mass is a deep gray labradorite which constitutes about one half of the rock. The next important mineral is the augite which makes a large percentage of the dark minerals. Olivine is found in large quantities.

Andesite, Elkhorn.

On Elkhorn Peak the andesite is one thousand feet thick, and has a typically dense, dark, and fine grained appearance. The ground mass consists of small laths of plagioclase, and sprinkled over the entire mass are small plates of biotite and hornblende. Some augite, and a very small amount of magnetite. is found.

Diorite-Porphyry, Elkhorn.

The ground mass is fine grained and gray in color. Embedded in this are plagioclase phenocrysts, constituting one fourth of the mass by volume. Several percent of biotite and hornblende are found in clusters. The ground mass is quartz-orthoclase and plagioclase.

Aplite.

The piece of rock for this determination was taken froma bout a mile north of Elkhorn. It consists mostly of orthoclase and quartz with a small amount of plagioclase and accessory crystals of biotite and magnetite.

Hornstone, Elkhorn.

The hornstones are metamorphosed rocks which originally belonged to a clay series. Microgranitic felspar and quartz make up the ground mass. There is, also, a small amount of quartz and biotite flakes.

Quartz-Monzonite, Elkhorn.

The rock varies largely in the district. A section of rock taken about one mile west of Elkhorn containing about 30% labradorite. Orthoclase constitutes about 20%, while quartz equals 25%. About 7% each of biotite and hornblende is present with a little augite and magnatite.

Quartz-Monzonite, Boulder.

The rock had somewhat a fresh appearance compared with the granite from other places, and gave about the following composition: Quartz 20%, Orthoclase 20%, Plagioclase 30% Hornblende, 15%, Biotite 5%, and a little Magnatite.

Butte Granite.

Butte granite is really a quartz-monzonite which strongly resembles the coarse diorite. It is dark colored, and coarsely granular. Orthoclase is the most abundant mineral, yet there is more plagioclase thant he ordinary granite contains. The texture is nearly porphyritic. To the un aided eye plagioclase, orthoclase, black hornblende, and black biotite, are easily distinguished. Undert he microscope, the rocks seem to vary between a hornblende granite and a quartz-diorite. The hornblende and biotite are fresh. The latter is dark brown in color and has a marked pleochroism. The accessory minerals are apatite, magnatite, pyrite, and zircon.

Bluebird Granite or Aplite.

The Bluebird granite is a finely granular silicious granite consisting of the alkali-felspar and quartz. It contains a few scattered grains of biotite and a very small amount of plagioclase. It strongly resembles sandstone, the texture is sugary, and the color varies between a white and a cream color. Under the microscope, it shows orthoclase, rounded quartz grains, and occasional flakes of biotite.

Quartz (Modoc) Porphyry, Butte.

The quartz-porphyry is pale green in color, andcontains opaque white felspar. Occasionally well formed crystals of orthoclase are found, and usually a small amount of epidote. The ground mass is very dense and often shows a peppering of mica plates. Under the microscope, the sections show a typical quartz porphyry of very uniform character. The felspars are usually orthoclase and rarely plagioclase. The ground mass which is often altered, to sericite and clay, is very crystaline.

Rhyolite, Butte.

Two distinct varieties are found, intrusive and extrusive. One marked peculiarity of the rhyolites is that they contain an abundance of biotite mica. They vary from glassy forms to very dense varieties. They usually show phenocrysts of white felspar, glassy quartz and black mica. The color ranges from light to dark gray. Specimens studied under the microscope show both orthoclase (sanadine) and plagioclase, felspars, with the former predominating. As the dike walls are approached the texture becomes denser, and the porphyritic crystals smaller.

Gabbro from North of Helena.

The coarseness of grain in this rock varies from about one fiftieth to one twelfth of an inch. The labradorite appears extremely uniform and shows no zonal structure. The augite is very light, but a clear brown, showing an irregular cleavage. Magnatite is present in small amounts, as is, also, clear brown biotite.

Felspar Porphyry from near Marysville.

The most noticeable constituent is the plagioclase. This is present in phenocrysts from an eighth to a quarter of an inch in diameter. With the felspar are found crystals of pale green biotite and hornblende. These lie in a dark gray or greenish microcrystaline ground mass which, under the microscope, reveals itself as composed of small tabular shaped felspar crystals, mostly plagioclase. Some quartz is also seen. A rock of more striking appearance could be found only with difficulty.

Quartz-Diorite from Marysville.

The freshly broken rock is fairly coarse and even grained, uniform in appearance and possesses biotite in amount equal to that of the hornblende. The plagioclase is frequently twinned, and comprises over one half of the rock. The dark minerals, biotite and hornblende, comprise about one fifteenth of the volume each. Some iron minerals are also seen.

Quartz-Monzonite from Unionville.

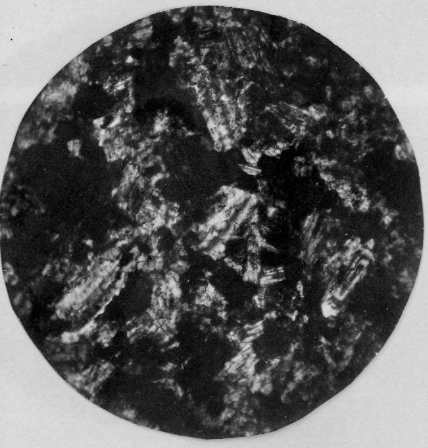
Several slides were made of this rock showing different conditions. The unalteredhand specimen presents an extremely uniform and fine texture. The light quartz and felspar do not appear much more numerous than are the dark minerals. This is caused by the small size and arrangement of the different colored constituents. The peppry appearance is particularly noticeable when the rock in question is placed beside the more coarsely crystalized specimens of Butte granite. One slide was made showing a small quartz dike cutting themonzonite. The quartz evidently was deposited in a joint plane. Along the former joint, Iron ore and kaoline were seen in small amounts. A thin section was made showing one of the dark spots in themonzonite. The spot in the thin section is of a light green tint with small flakes of slightly darker green hornblende arranged indistinctly paralle positions. No biotite or other mica was seen. Also, a thin section was made of a specimen from the wall of a dike that was traced directly into the batholith. The rock is a typical gray rhyolite, in the hand differently textured portions. The portion next to the wall was the finer of the two.

Spring Hill Diorite, near Helena.

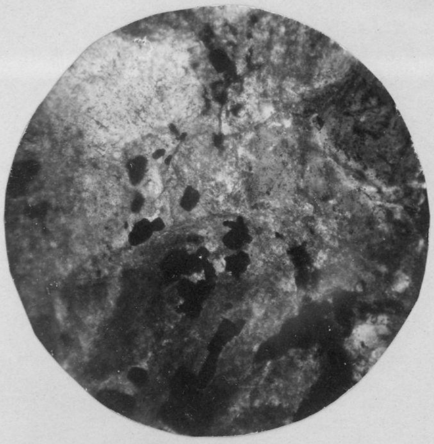
Two sections of this rock were made. One was of the fresh, unaltered rock. It exhibited the normal diorite composition. Most of the dark mineral is hornblende, mica being scarce. The plagioclase does not include any labradorite. The other section was of a piece of the same mass taken from the cut at the Spring Hill mine. It had very little dark mineral remaining, and has apparently been silicified in threads and tabular masses.

Oolitic Limestone from Marysville.

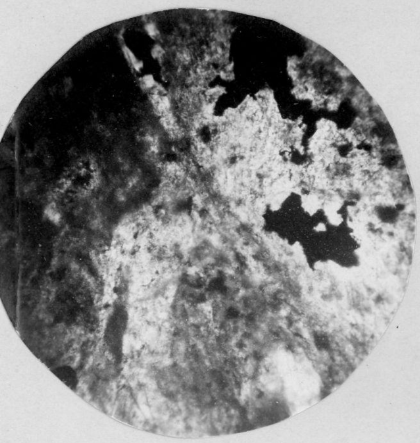
Oolitic limestone has been found in the Helena limestone both at Marysville and near Helena. The specimen studied was taken from the former place. The Oolite is frequently porous, the spaces between the nodules being unfilled. Under the microscope the nodules are seen to consist of a nucleus of calcite, sometimes rhombohedral in form, surrounded by a thickness of five times as much silica. The silica is deposited around the calcite center.



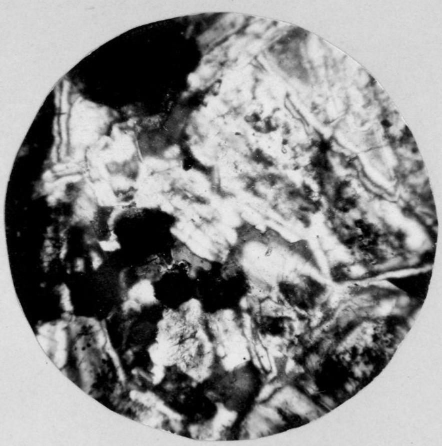
Gabbro -
Elkhorn



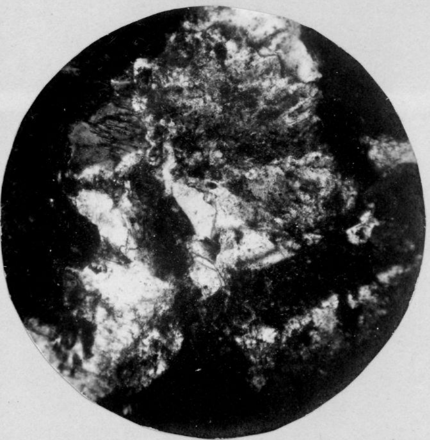
Mineralized aplite -
Butte



Mineralized aplite -
Butte

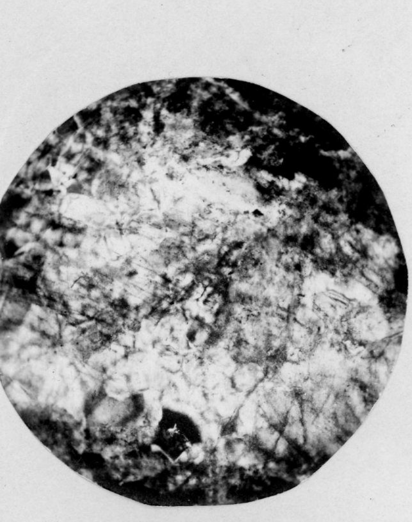


Granite -
Butte



Granite - Elkhorn

Diabase from Elkhorn



etamorphosed rock from Helena

Mineralized aplite from Butte